

A2 —Accordingly, it is a primary object of the present invention to provide a method to maximize a communication parameter in a channel between a wireless transmit unit and receive unit, both using multiple antennas. Specifically, the method should permit the system to continuously optimize data capacity, signal-to-noise ratio, signal quality, throughput and other desirable parameters while the channel varies. —

Please replace the paragraph beginning at line 18 of page 6 with the following rewritten paragraph:

A3 —It is a further object of the invention to provide a method which takes full advantage of multiple antennas at the transmit unit and receive unit to optimize a communication parameter of the channel using a quality parameter derived from the received signals. —

Please replace the paragraph beginning at line 24 of page 6 with the following rewritten paragraph:

A4 —Yet another object of the invention is to provide a method as indicated above in any wireless communication system using any combination of multiple access techniques such as TDMA, FDMA, CDMA, and OFDMA. —

Please replace the paragraph beginning at line 27 of page 7 with the following rewritten paragraph:

A5 —In a preferred embodiment, each of the spatial-multiplexed streams  $SM_i$  is processed by a coding unit to produce coded streams  $CS_h$ , where  $h=1...k'$ . The quality parameter is utilized in the transmitter to adjust the coding, e.g., by changing  $k'$ , used by the coding unit. The coding unit can be a space-time coder, a space-frequency coder, an adaptive modulation rate coder or other suitable coding device. The space-time and space-frequency coders can use different coding and modulation rates. —

Please replace the paragraph beginning at line 1 of page 11 with the following rewritten paragraph:

A6 —The communication system can employ any one or more of the available multiple access techniques such as TDMA, FDMA, CDMA, OFDMA. This can be done in a wireless system, e.g., a cellular communication system. —

Please replace the paragraph beginning at line 1 of page 13 with the following rewritten paragraph:

A7  
Cont.  
A —The time variation of channels **22A**, **22B** causes transmitted TS signals to experience fluctuating levels of attenuation, interference, multi-path fading and other deleterious effects. Therefore, communication parameters of channels **22A**, **22B** such as data capacity, signal quality or throughput undergo temporal changes. Thus, channels **22A**, **22B** can not at all times support efficient propagation of high data rate signals RS or signals which are not formatted with a robust coding algorithm. Antenna array **16** at BTS

Q7  
Q8  
12 can be used for spatial multiplexing, transmit diversity, beamforming to reduce interference, increase array gain and achieve other advantageous effects. Antenna arrays 20 at receive units 14 can be used for spatial multiplexing, interference canceling, receive diversity, increased array gain and other advantageous effects. All of these methods improve the capacity of channels 22A, 22B. The method of the invention finds an optimum combination of these techniques chosen adaptively with changing conditions of channels 22A, 22B. In other words, the method of the invention implements an adaptive and optimal selection of order of spatial multiplexing, order of diversity as well as rate of coding and bit-loading over transmit antenna array 16 to antenna array 20. —

Please replace the paragraph beginning at line 19 of page 14 with the following rewritten paragraph:

Q8  
—The details of a preferred embodiment of a transmit unit 50 for practicing the method of the invention are shown in Fig. 3. Data 52 to be transmitted is delivered to a data processing block 54, where it first passes through an interleaver and pre-coder 56. Interleaver and pre-coder 56 interleaves and pre-codes the stream of data 52, as is known in the art and sends the interleaved and pre-coded stream to serial to parallel converter 58. Converter 58, produces from the single data stream a number  $k$  of spatial-multiplexed streams  $SM_i$ , where  $i=1\dots k$  and  $k$  is a variable, i.e., the number of streams  $SM_i$  is variable, subject to the condition that  $1 \leq k \leq N$  and also  $k \leq M$ . In other words, the maximum number  $k$  of streams  $SM_i$  is limited by the smaller of the number  $M$  of transmit antennas  $TA_1, TA_2, \dots, TA_M$  and the number  $N$  of receive antennas  $RA_1, RA_2, \dots, RA_N$  (see Fig. 4). —

Please replace the paragraph beginning at line 19 of page 15 with the following rewritten paragraph:

Q9  
—Each of the  $k$  streams  $SM_i$  passes through a corresponding Space-Time Coder 65 (S-T Coder) of an S-T Coding Unit 66. Each S-T Coder produces  $k'$  coded streams  $CS_h$ , where  $h=1\dots k'$ . The number  $k'$  is at least 1 and at most  $M$ , depending on the number of streams  $SM_i$  selected by adaptive controller 60. In fact, adaptive controller 60 is also connected to S-T Coding unit 66 to also control the number  $k'$ . —

Please replace the paragraph beginning at line 17 of page 17 with the following rewritten paragraph:

Q10  
cont.  
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38<sup>3</sup>  
—For example, if the quality parameter which is fed back is SINR and the aim is to improve the throughput, then database 68 will contain the performance curves (BER versus SINR) for different S-T codes for all possible transmit/receive configurations in terms of number  $M$  of transmit antennas  $TA_1, TA_2, \dots, TA_M$  and number  $N$  of receive antennas  $RA_1, RA_2, \dots, RA_N$ . Fig. 8 shows the performance of three typical S-T codes. As can be seen, to achieve a BER of value  $q$ , which is suitable for the application (e.g., voice data transmission), when the prevailing average SINR has to have a value  $p$  or less, only S-T codes 1 and 2 are suitable. S-T code 3 is not suitable because at SINR value  $p$  its BER is too high. Now, when the communication parameter to be maximized is the throughput, an additional choice is to be made between S-T code 1 and S-T code 2, and

the one maximizing throughput is selected. A person of average skill in the art will see that this process or a similar process can be employed to maximize any of the communication parameters. In addition, preferably, database 68 contains the necessary performance curves to select the proper S-T codes, values of k and G(z) matrix sets to use. However, empirically collected data may also be used. —

Please replace the paragraph beginning at line 6 of page 19 with the following rewritten paragraph:

—Preferably, database 68 is also connected to unit 72 and contains stored parameters of suitable matrix sets G(z) for any given channel conditions or the matrix sets G(z) themselves. In the latter case adaptive controller 60, which is also connected to database 68, instructs database 68 to download the appropriate matrix set G(z) into transmit processing unit 72 as the channel conditions change. The choice of matrix set G(z) is made to facilitate the separability of the k spatial-multiplexed streams SM<sub>i</sub> at the receiver. Matrix set G(z) can incorporate diversity techniques such as delay/switched diversity or any other combining techniques known in the art. For example, when no channel information is available at transmit unit 50, e.g., at system initialization or at any other time, then matrix set G(z) (which consists of k MxM matrices) is made up of k matrices of rank M\*k such that the subspaces spanned by these matrices are mutually orthogonal to ensure separability of k streams at receive unit 80. The task of finding such matrices can be performed by a person of average skill in the art. During operation, as the quality parameter changes, other sets of matrices G(z) can be also used. —

Please replace the paragraph beginning at line 1 of page 21 with the following rewritten paragraph:

—Matrix channel estimator 84 estimates the channel coefficients using known training patterns, e.g., the training patterns provided by training unit 70 in accordance with known techniques. In the present case, the output of estimator 84 is  $\hat{A}(z)$ :

$$\hat{A}(z) = G(z)H(z),$$

where G(z) is the matrix applied by transmit processing block 72, and H(z) is the matrix of pure channel coefficients. G(z) is a set of MxM matrices while H(z) is an MxN matrix. The resulting matrix  $\hat{A}(z)$  is an MxN matrix and represents channel estimates for received signals RS<sub>1</sub>, RS<sub>2</sub>, ..., RS<sub>N</sub> after digitization. The channel estimates supplied to receive processing block 86 by estimator 84 are used by the latter to recover the k spatial-multiplexed streams SM<sub>i</sub>. In fact, any of the well-known receive processing techniques such as zero-forcing (ZF), MMSE, LS, ML etc. can be used for processing received signals RS<sub>1</sub>, RS<sub>2</sub>, ..., RS<sub>N</sub>. —

Please replace the paragraph beginning at line 1 of page <sup>23</sup>21 with the following rewritten paragraph:

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